

Influence of rainforest architectural and biological diversity on C assimilation along an elevation gradient in Hawaii

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Outline

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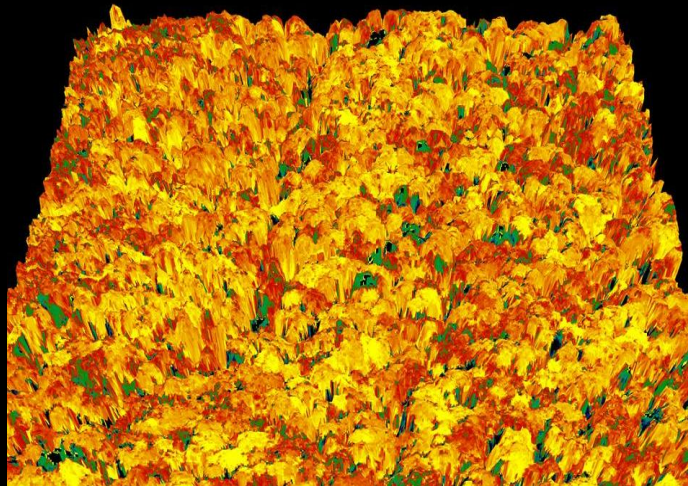
Overview

- Carbon accumulation in plants is a major component of the global carbon cycle (~ 15 Pg C/year). Carbon dynamics will be altered by future climatic changes, including changes in temperature and precipitation.
- Carbon models have not included detailed 3-D maps of forest foliage distribution. Course scale estimates indicate that the inclusion of foliage profiles could result in $\sim 50\%$ differences in calculated GPP.
- Little understanding of the role architectural diversity vs. biological diversity may play in carbon dynamics, and especially under different environmental conditions. However, recent technological advancements are now making new research questions feasible.

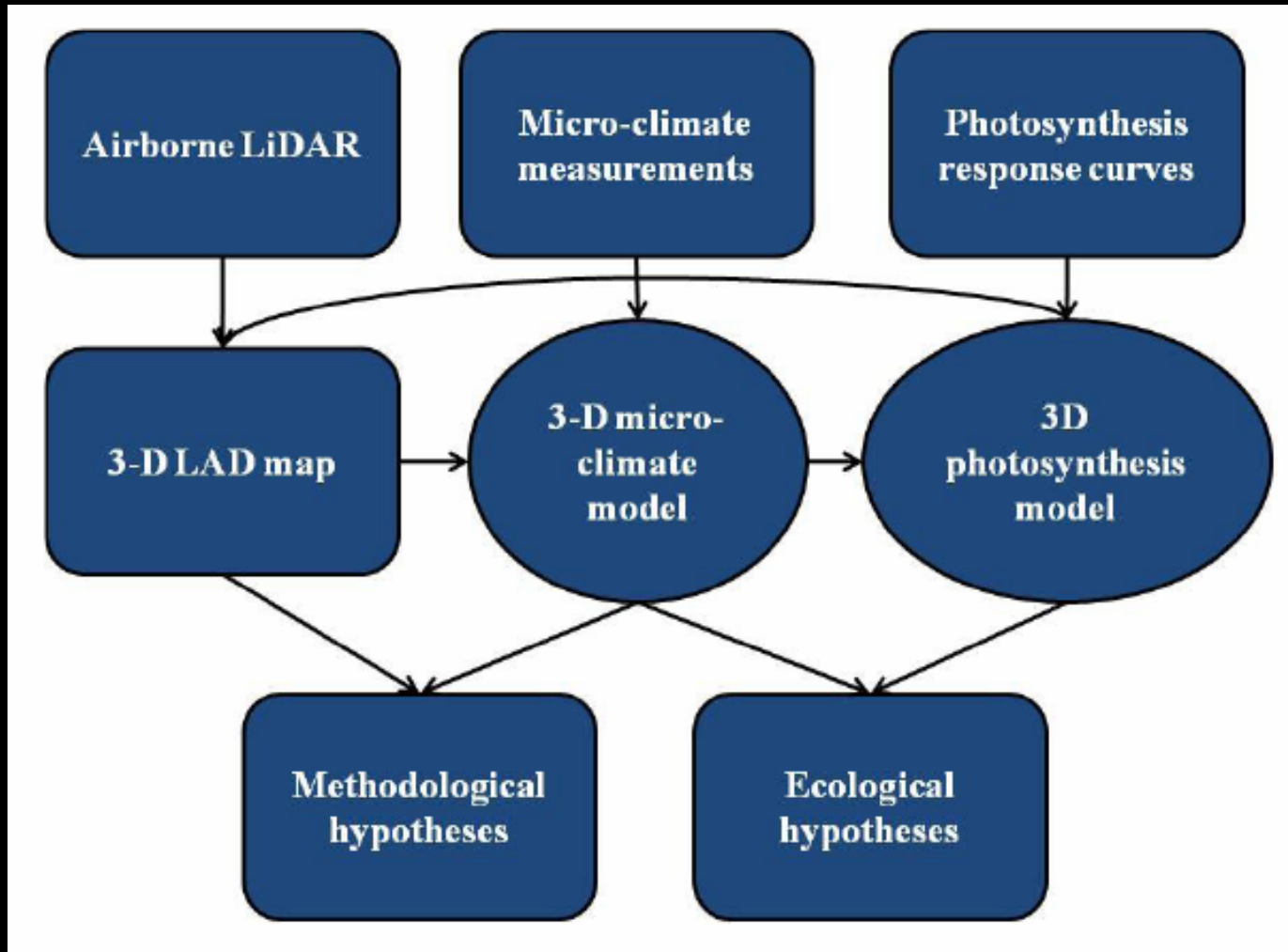


Overarching research questions

- How does the inclusion of detailed forest structure alter modeled rates of forest C assimilation?
- How do architectural and biological diversity interact to define carbon assimilation under different temperature - precipitation regimes?

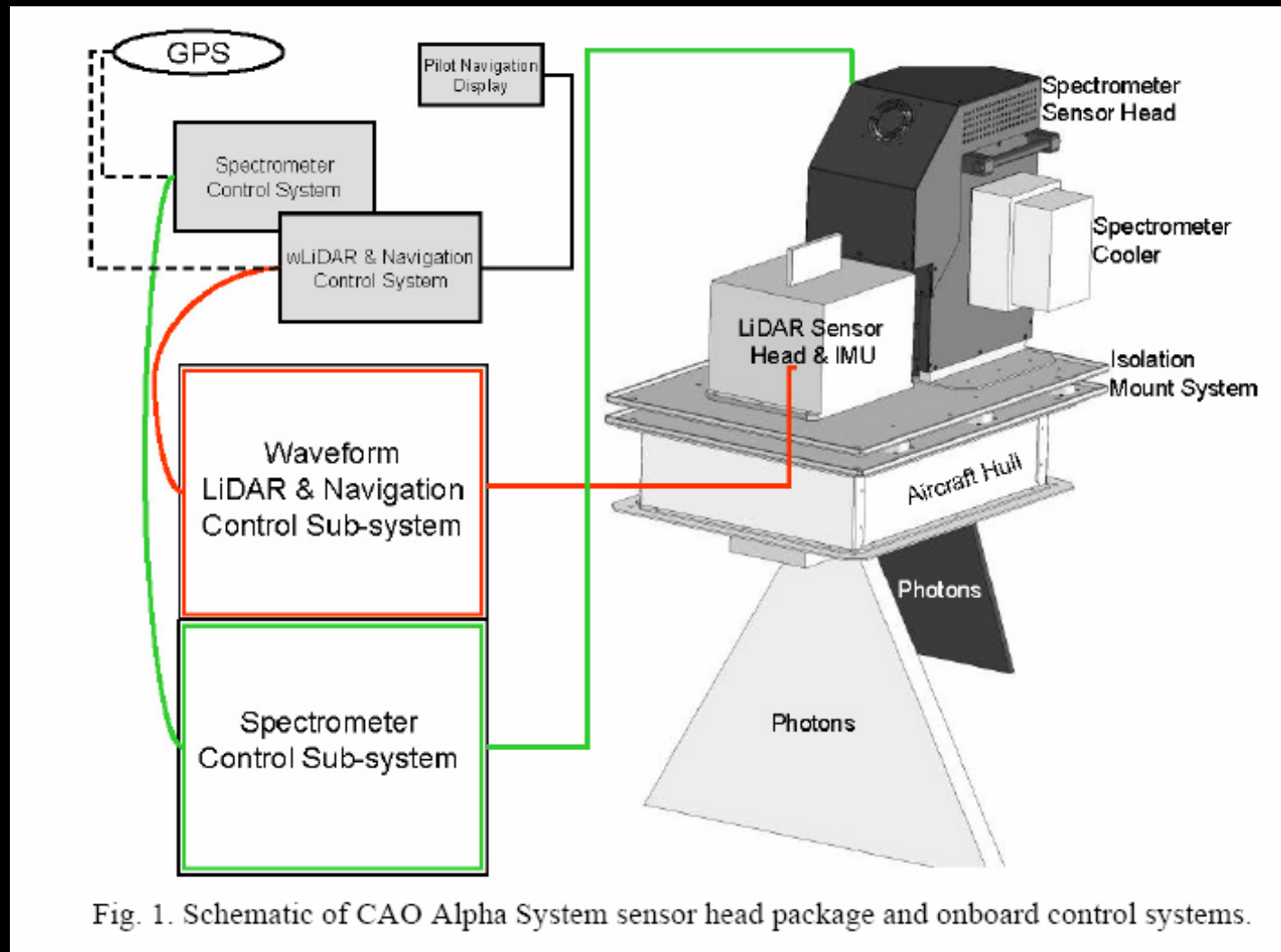


Approach



RS – LiDAR / hyperspectral fusion

Waveform light detection and ranging



Hyperspectral imaging

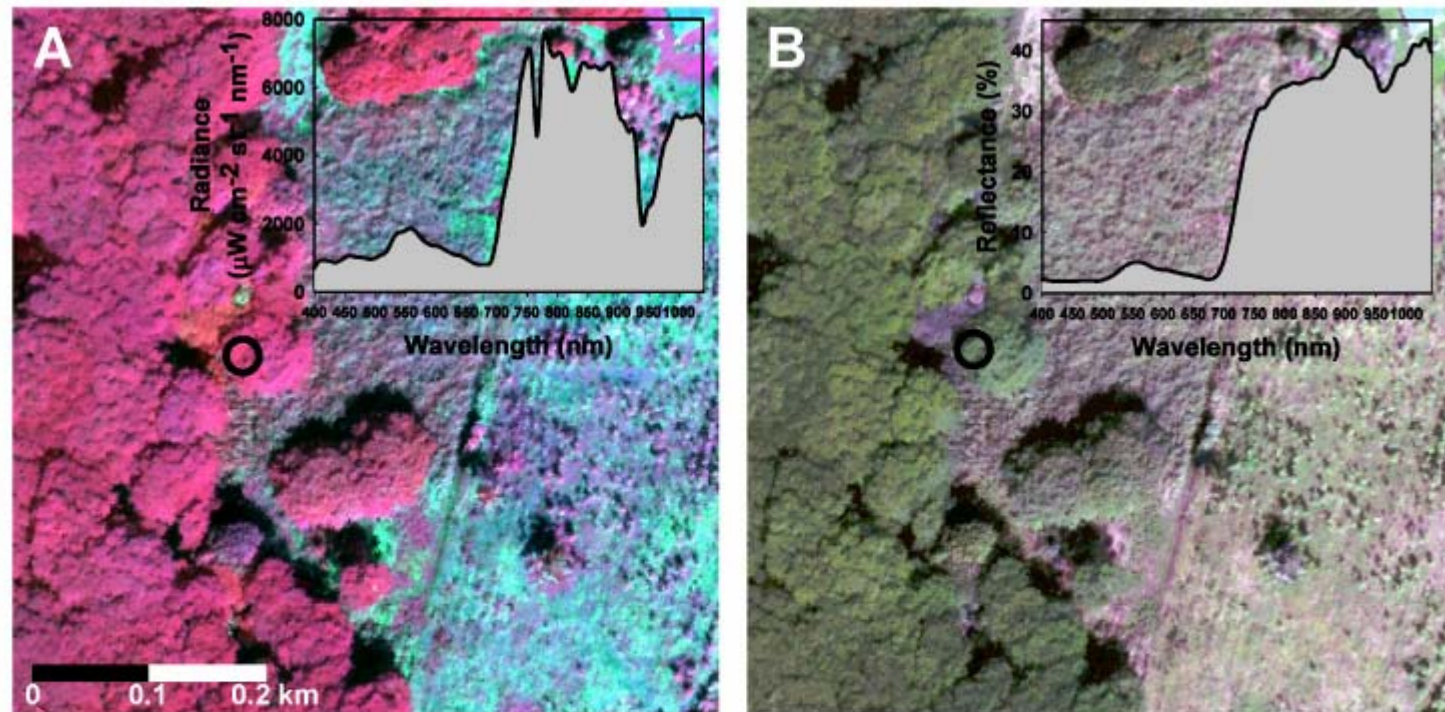


Fig. 8. Sample spectral images (0.45 m pixel size) of (a) radiance and (b) atmospherically-corrected reflectance. Insets show example radiance and reflectance spectra from indicated circle for wavelengths spanning 367-1052 nm.

Waveform LiDAR

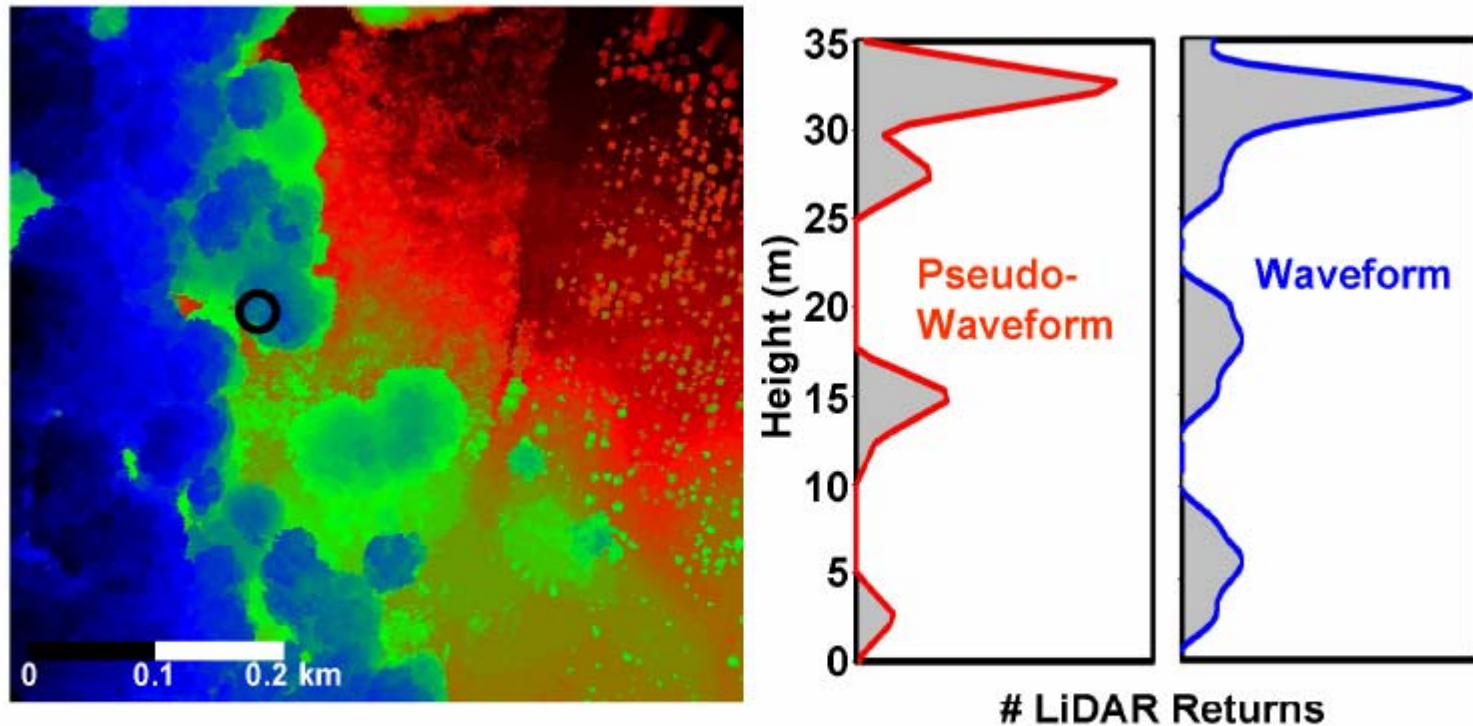


Fig. 9. Sample LiDAR first surface (vegetation and ground) image of same area shown in Fig. 8. Tall trees are shown in blue with progressively shorter vegetation in green and red. Also shown are the extracted waveform and a pseudo-waveform from canopy pixel in the black circle.

Surface topography

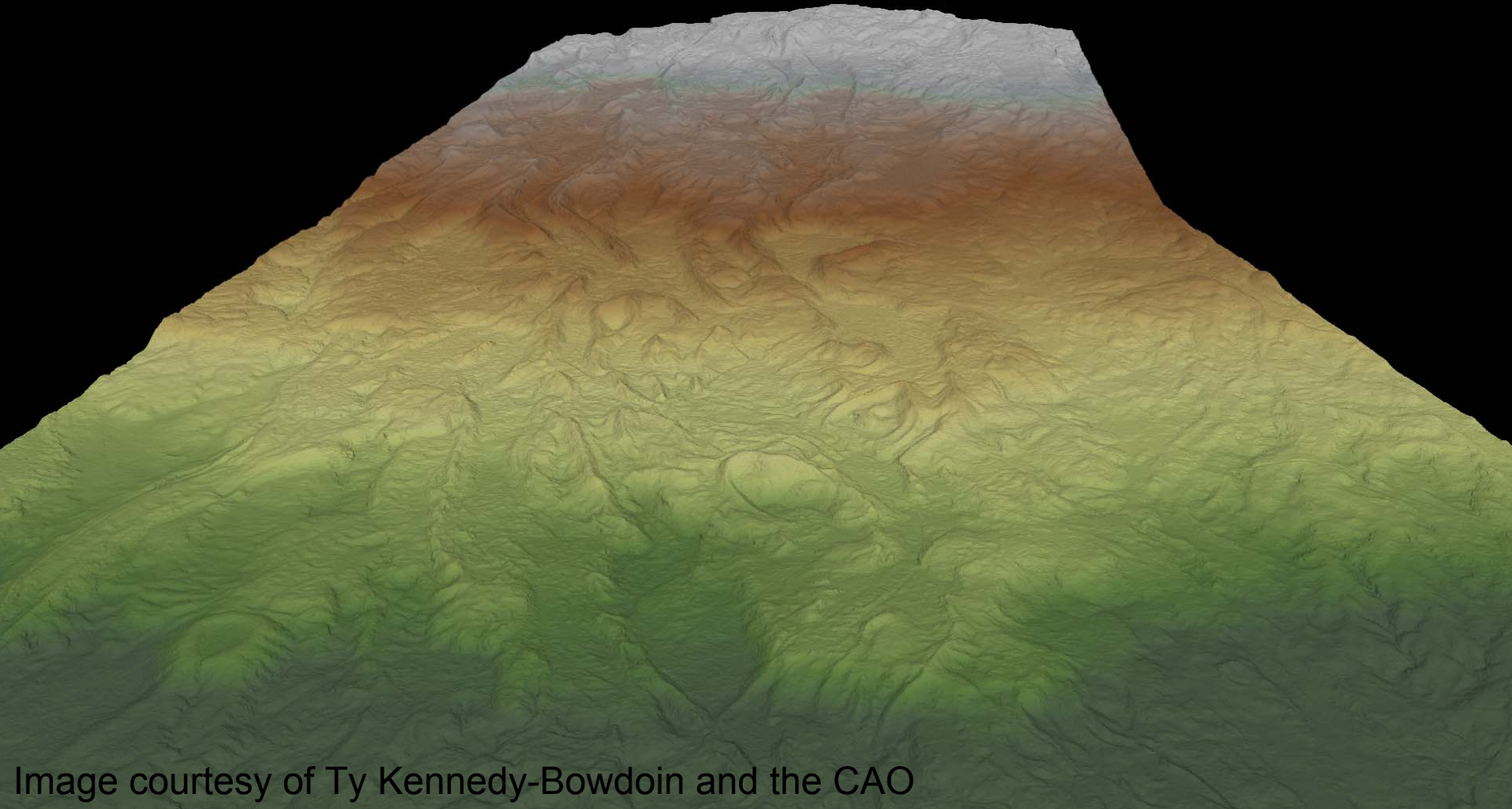


Image courtesy of Ty Kennedy-Bowdoin and the CAO

Max canopy height

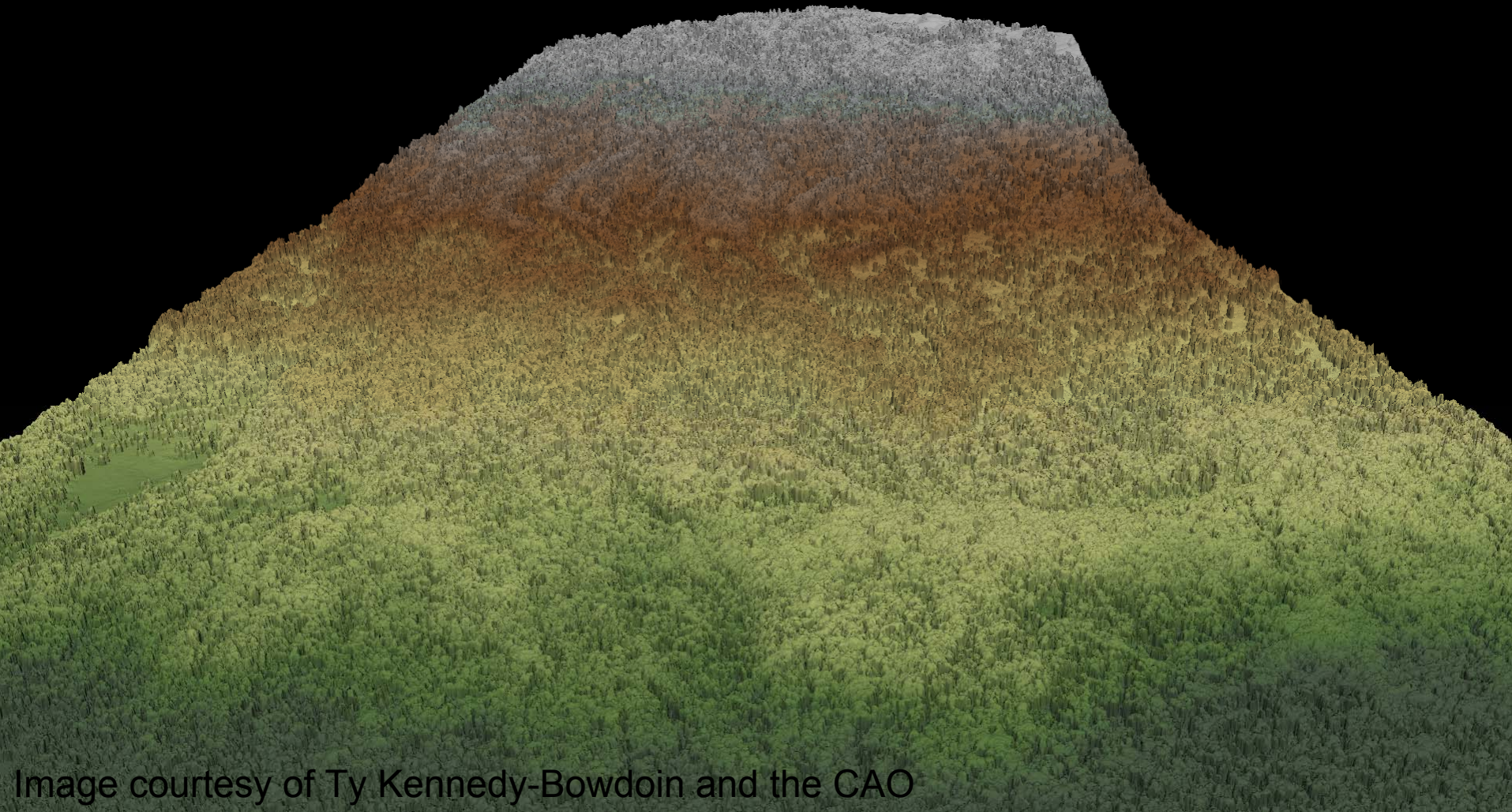
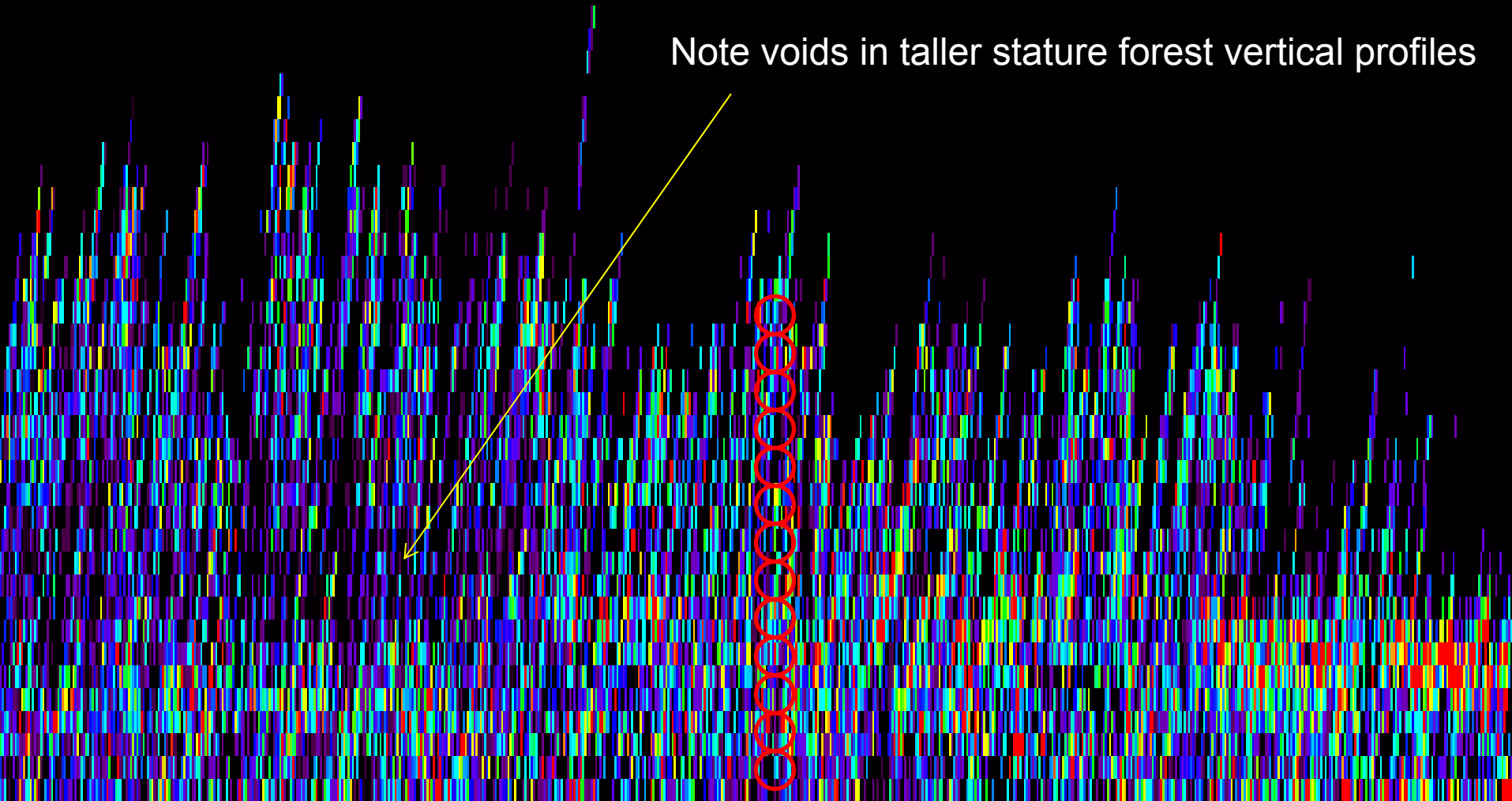


Image courtesy of Ty Kennedy-Bowdoin and the CAO

Example. Vertical forest leaf area density profile
(red = high, blue = low, black = no biomass)



Data fusion — waveform + hyperspectral



Fig. 6. Example ray tracing results for in-flight fusion of CAO hyperspectral imaging and LiDAR data.

Research site:
Laupahoehoe, “Big island”, Hawaii



Laupahoehoe Experimental Forest

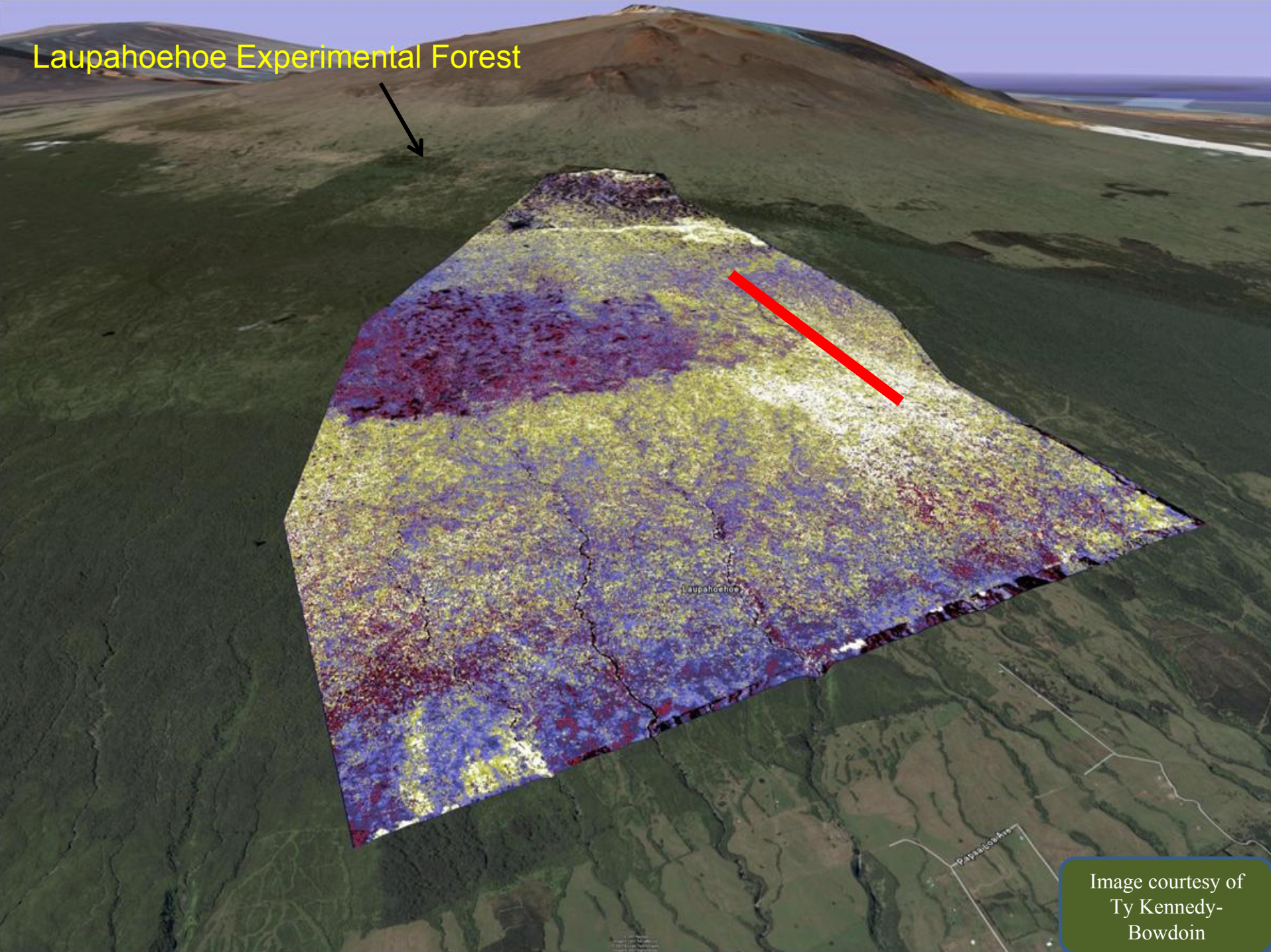


Image courtesy of
Ty Kennedy-
Bowdoin

Study transect location and description

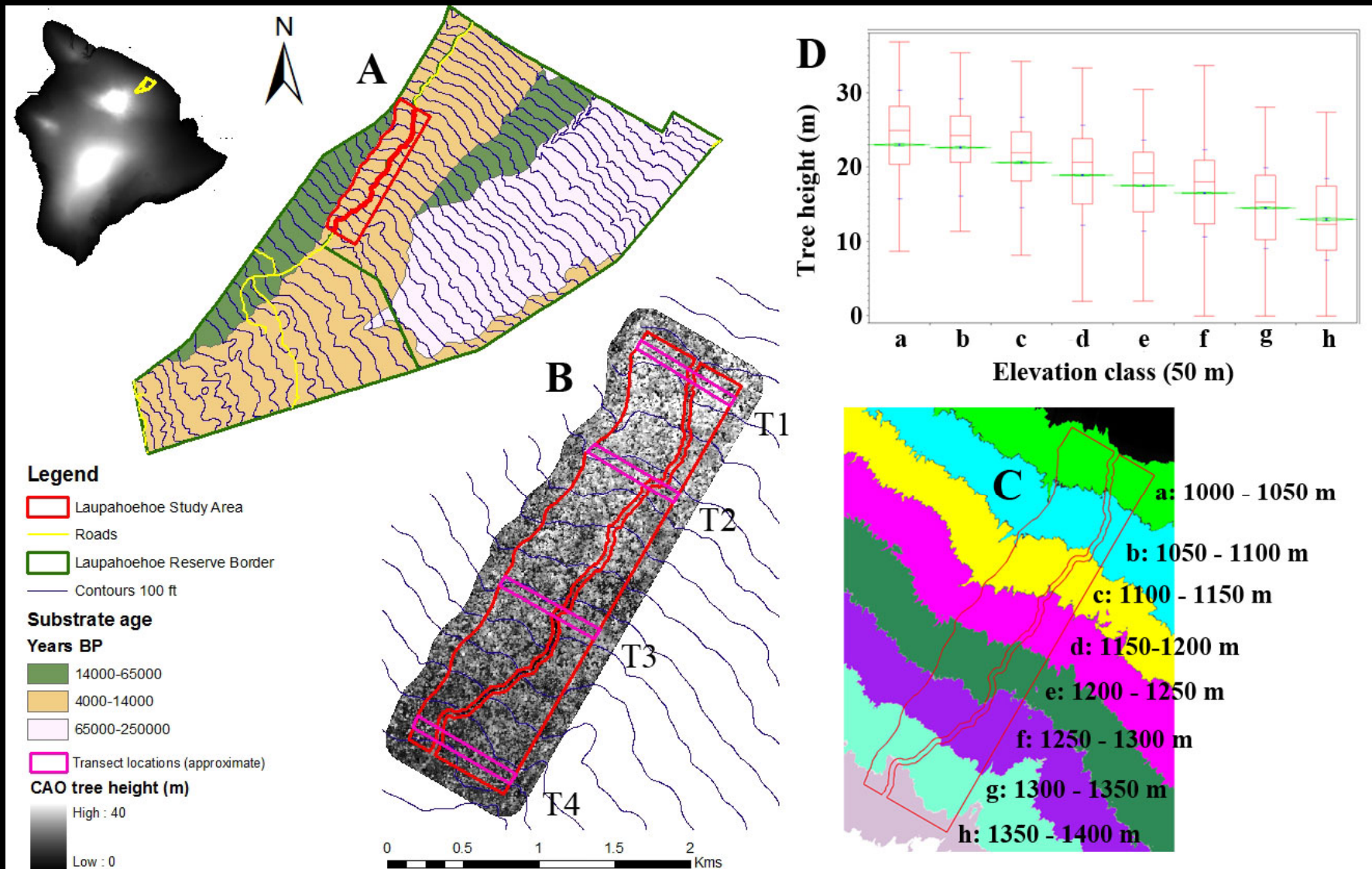
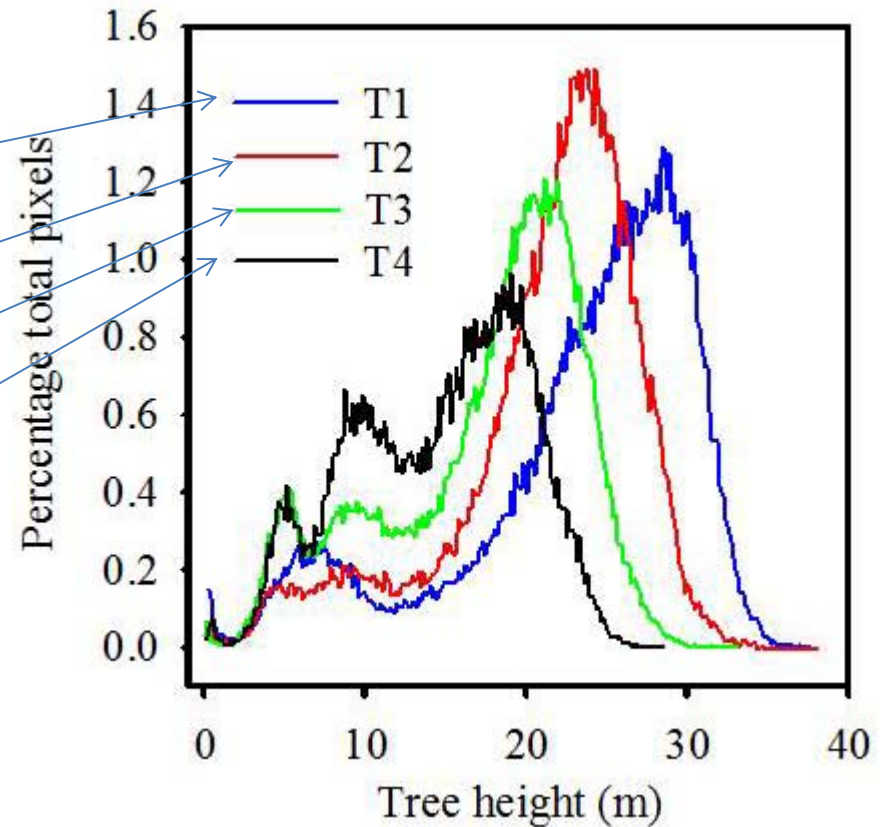
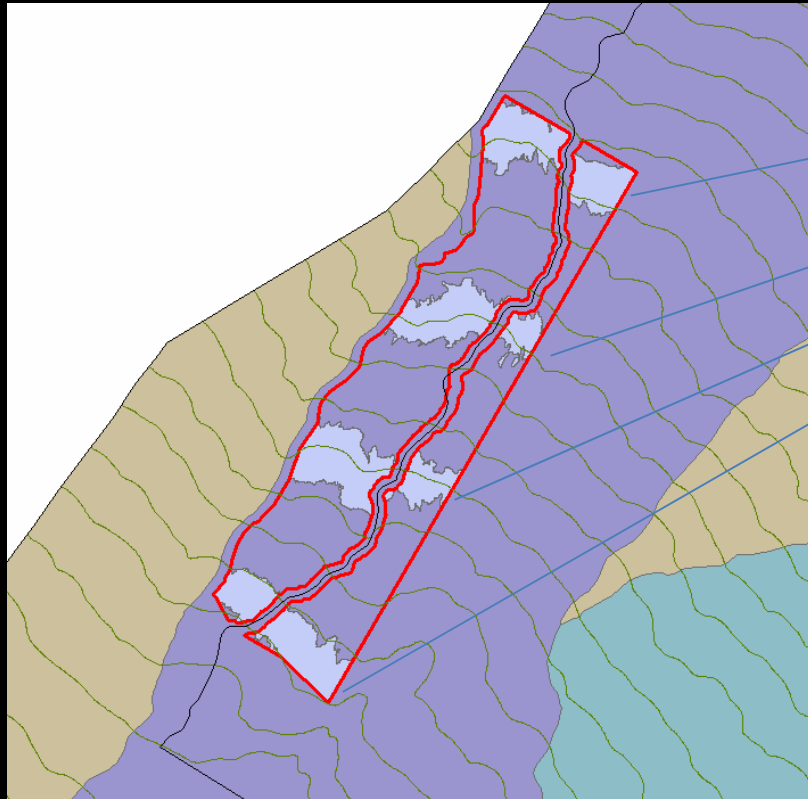


Fig. 1. Proposed study area in Laupahoehoe experimental forest, Hawaii. (A) Study area and soil age; (B) Tree height (m); (C) Elevation classes; and (D) mean (std. dev.) tree height (m).

Tree max canopy height distributions along the elevation transect



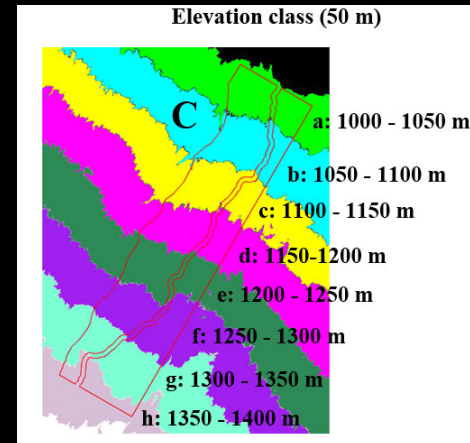
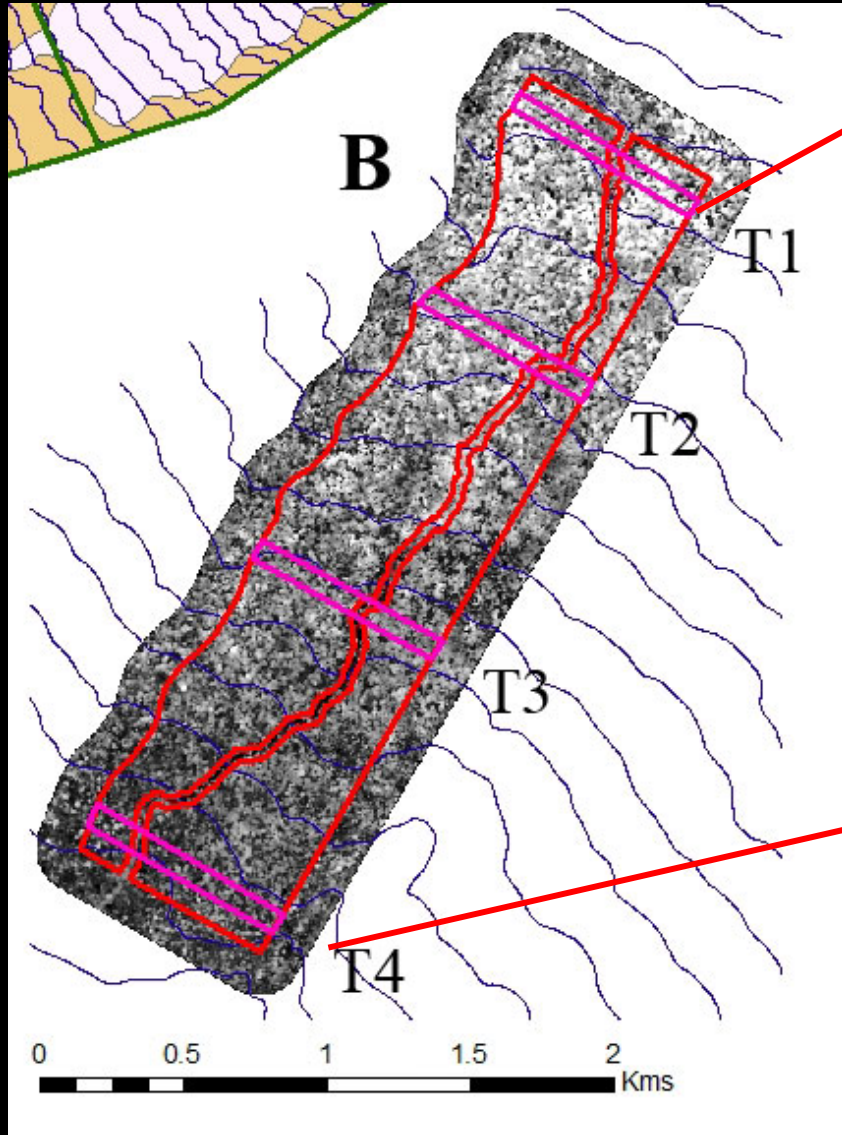
T1: 1010 - 1040 m

T2: 1110 - 1140 m

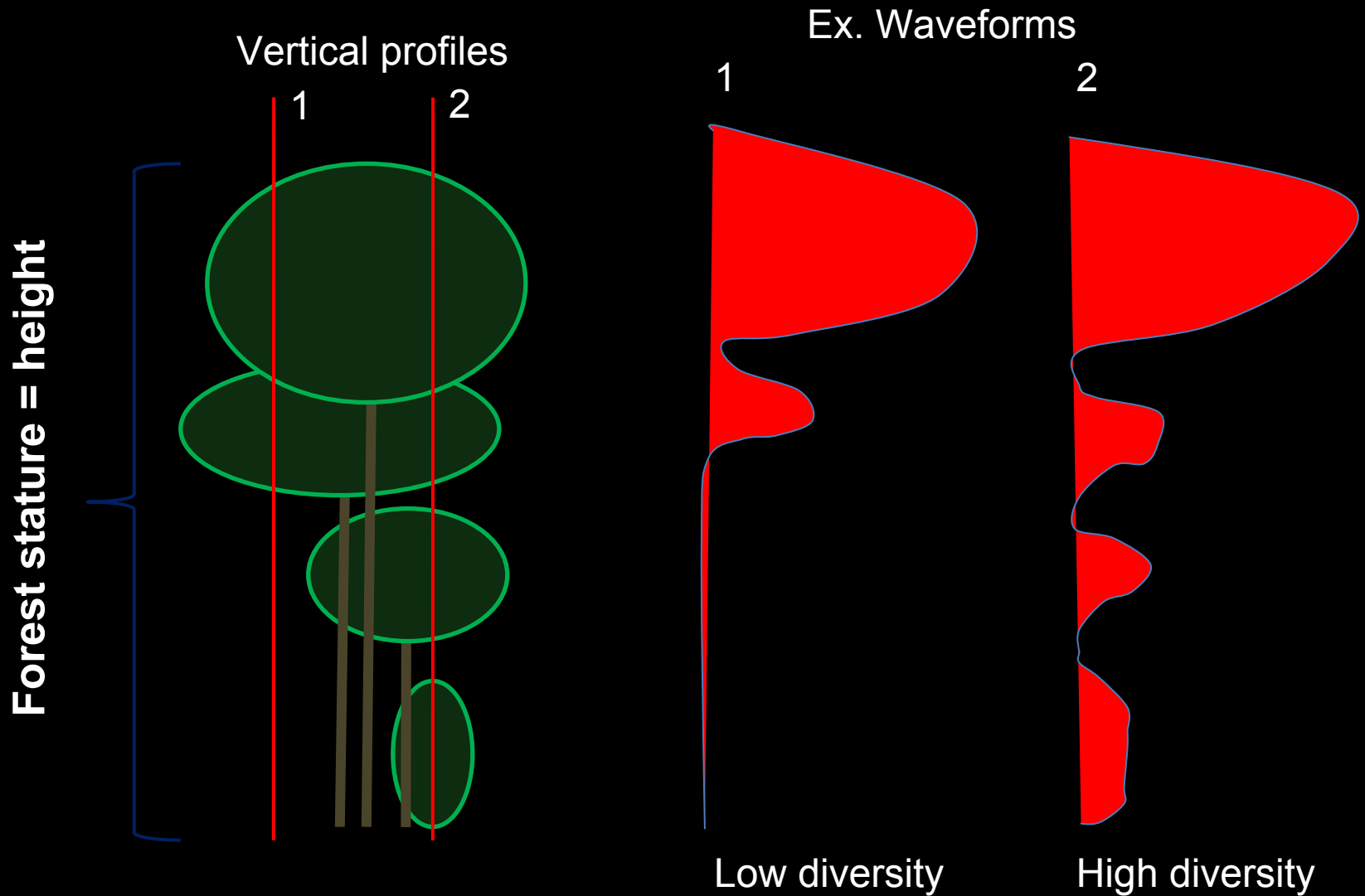
T3: 1210 - 1240 m

T4: 1310 - 1340 m

Changes in texture or horizontal architectural diversity

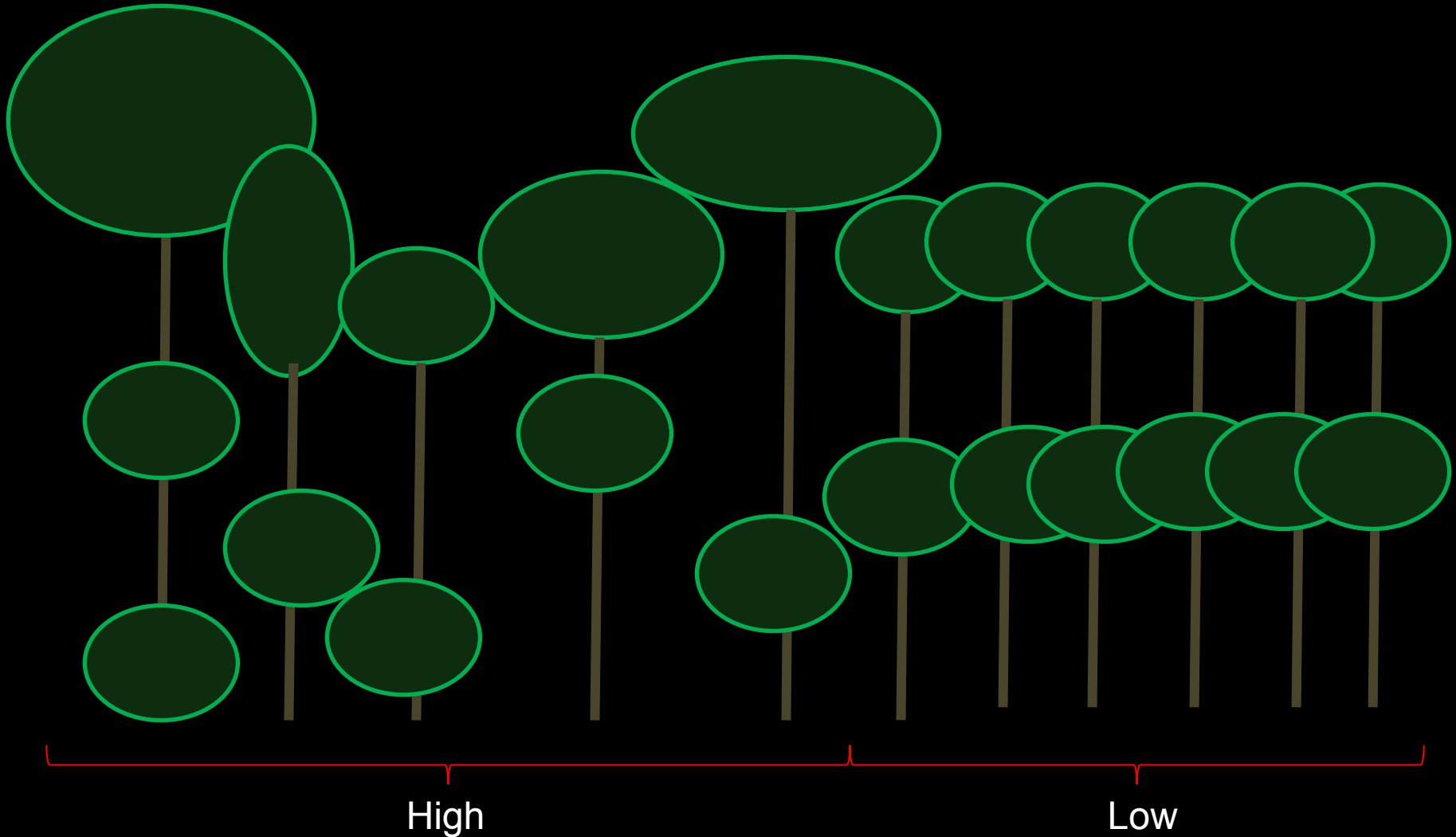


Definitions — moving beyond tree height



Architecture = understory biomass
distribution

Definitions



Forest heterogeneity – both in stature and architectural complexity

Site locations

- The identification of study sites within the transect has the goal of sampling across both the elevation gradient and the dominant types of forest architecture.

Input data:

- 1)Max canopy height
- 2)Forest architecture type
- 3)Canopy height variation
- 4)Elevation



However, forest structure is complex in three dimensions and varies along the elevation gradient.

So, leads to questions of:

1)What is forest architecture?

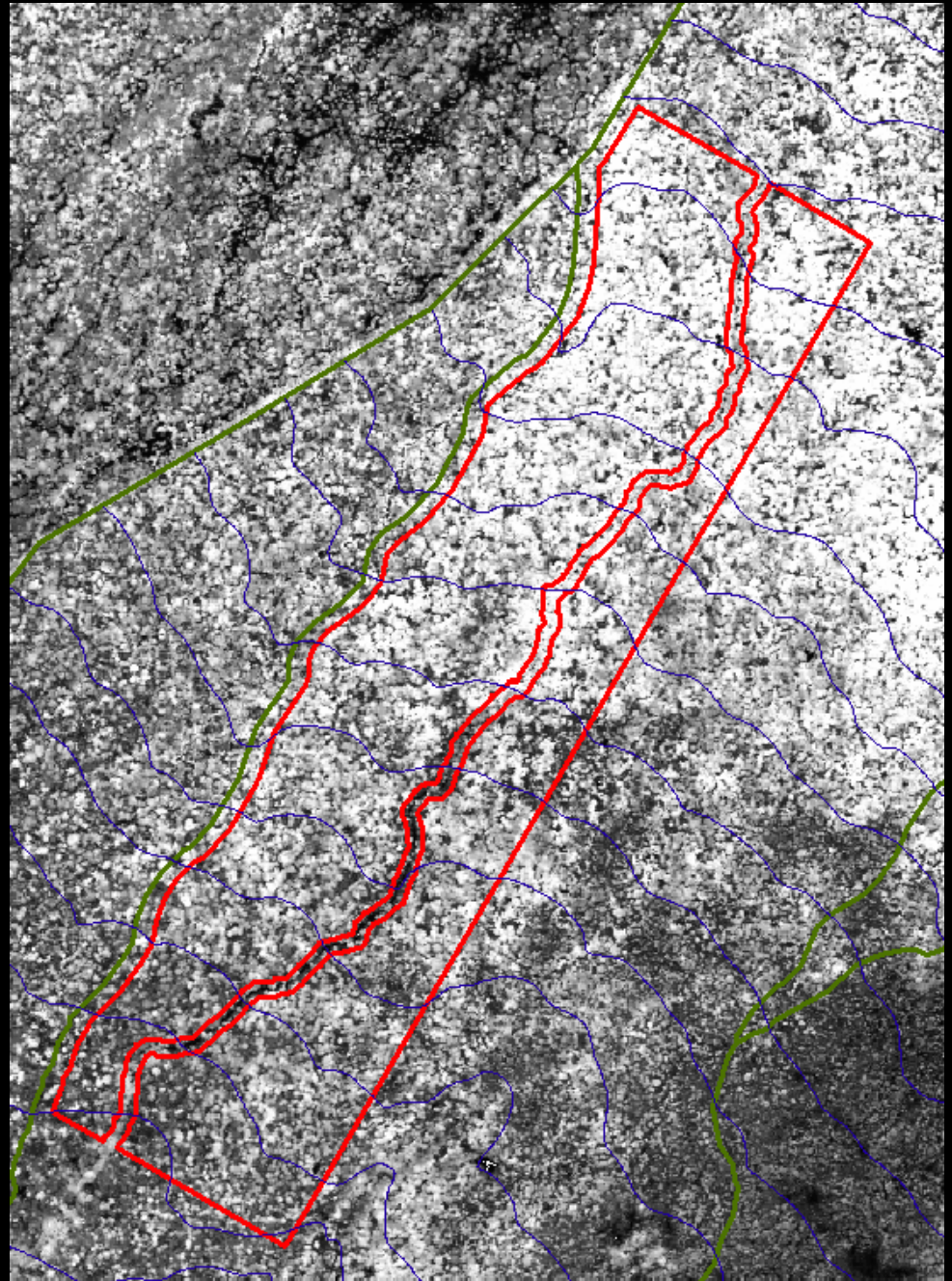
- a) New data types and resolutions require new metrics and definitions.

2)How to define/quantify?

- a) Plan to transition common community population diversity metrics to forest architectural diversity.

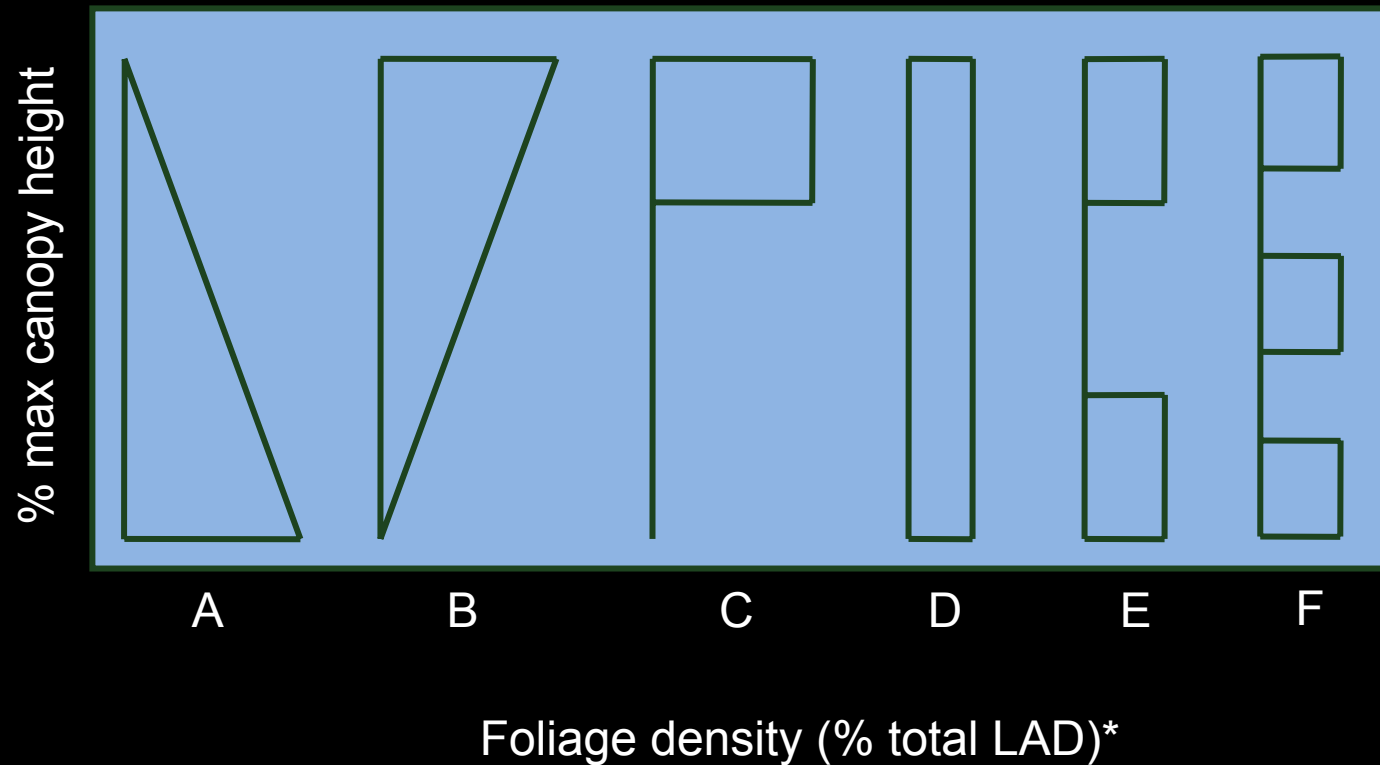
3)Categorical or continuous metrics?

- a) Determines statistical analyses and sampling designs.



Approach 1: categorical approach to quantifying forest architecture

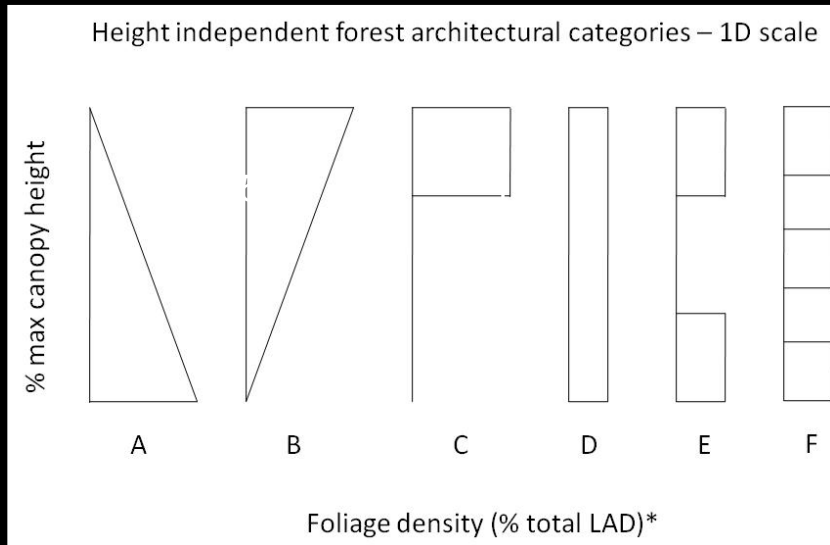
Height independent forest architectural categories



* In all cases, the summed area equals 100% vertical profile leaf area density (LAD)

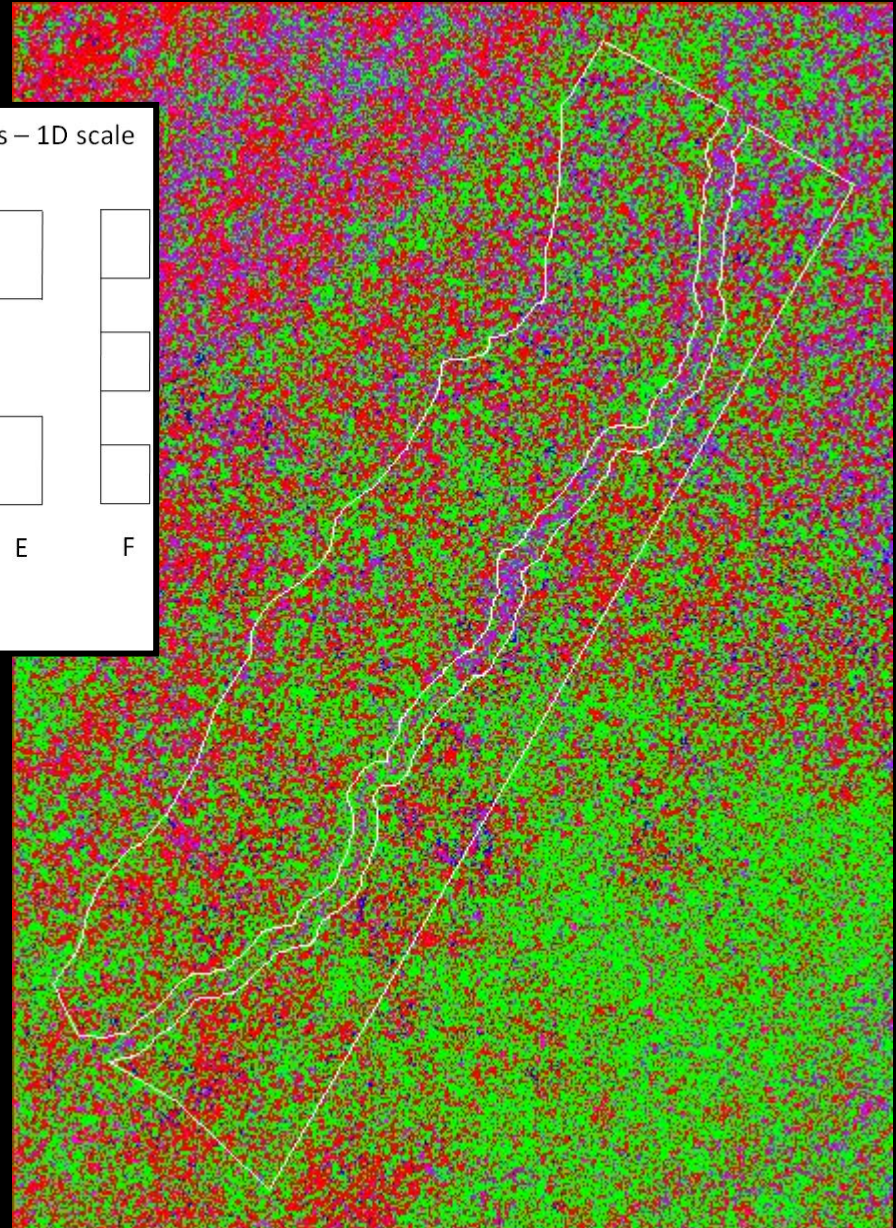
Architecture classified based on max LSU probability

A=Red
B=Green
C=Blue
D=Yellow
E=Purple
F=Magenta



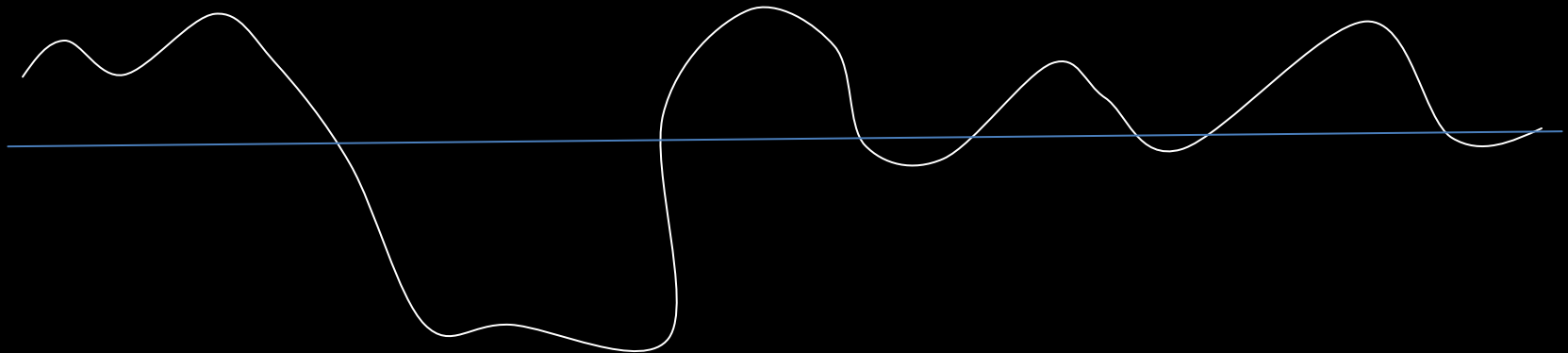
Results from classification over study area

Arch Type	Pixels	%
A	25068	36
B	31135	45
C	1787	3
D	0	0
E	8963	13
F	2352	3



Canopy height variation

- Canopy height variation is defined as the difference in canopy height between a specified pixel (different scales) and the mean canopy height across 30 m sections of elevation gradient (i.e., 1000 – 1030 m) within the study transect.



Does canopy height explain forest architecture?

- If canopy height (continuous variable) explains forest architectural type (categorical variable) I can locate my study plots along continuous gradients (elevation and deviation) versus replicating within a categorical variable.
- 300 points were randomly selected across the study transect and data exported to JMP.
- Mean canopy height significantly differed between dominant forest architectural categories.

Level		Mean
5	A	27.300275
3	B	25.848823
1	C	25.364878
2	D	23.668491
6	E	20.056865

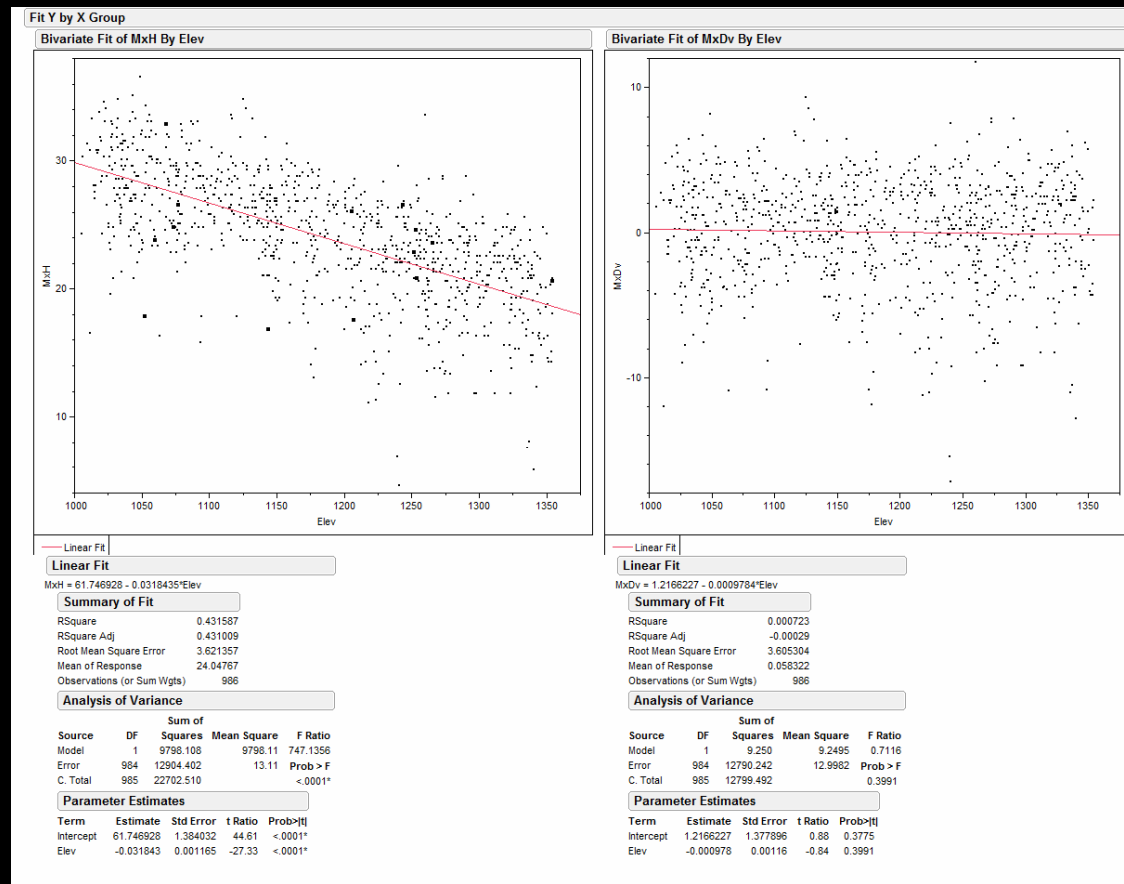
Levels not connected by same letter are significantly different.

Does elevation correlate with mean canopy height and/or height deviation?

If mean canopy height and/or deviation is significantly related with elevation then fewer variables are necessary to consider when selecting study sites.

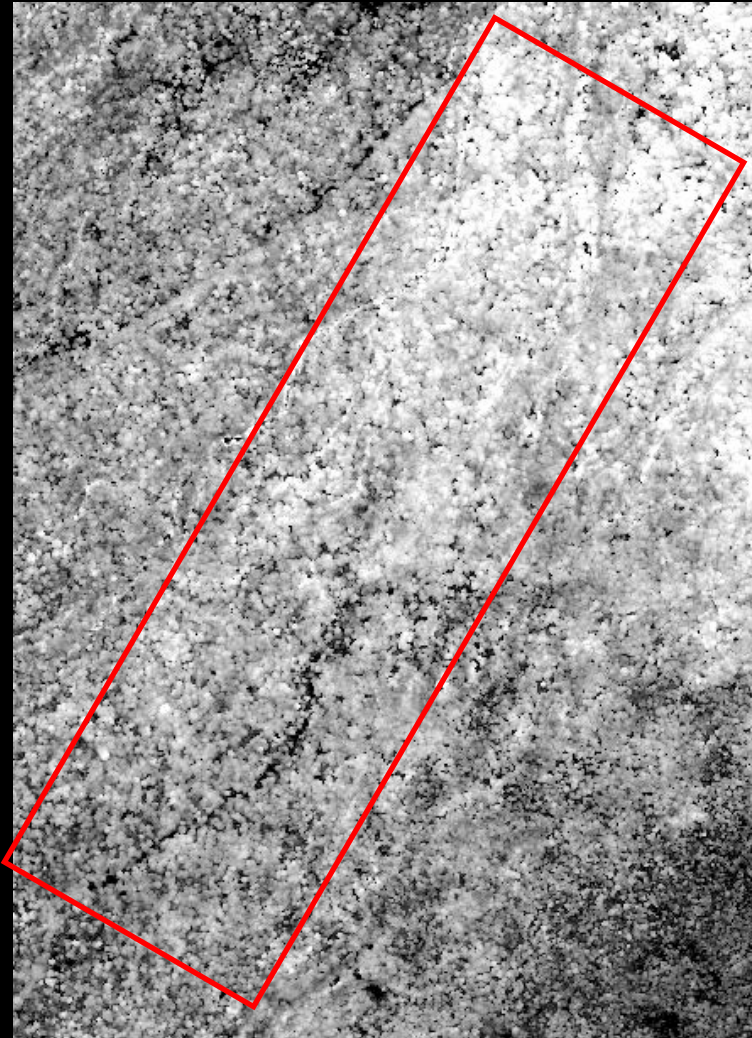
1000 points were randomly selected across the study transect and data exported to JMP.

Elevation explains max canopy height but does NOT explain height deviation.

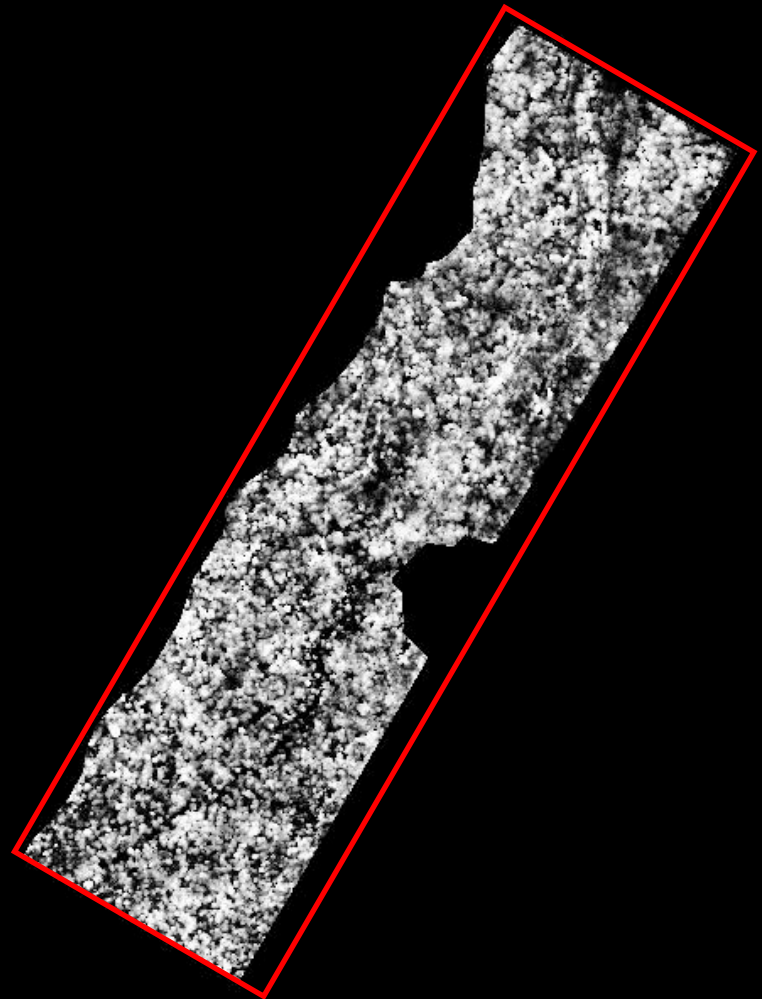


Max height vs. height deviation

Max canopy height

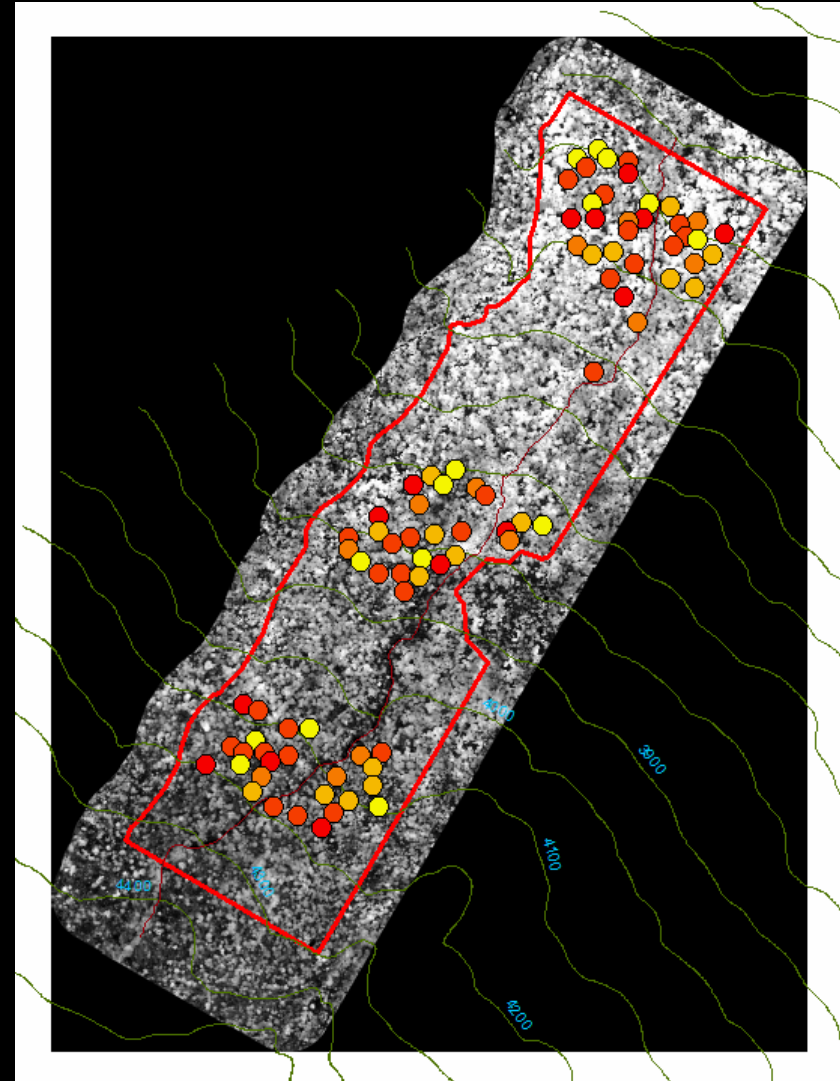
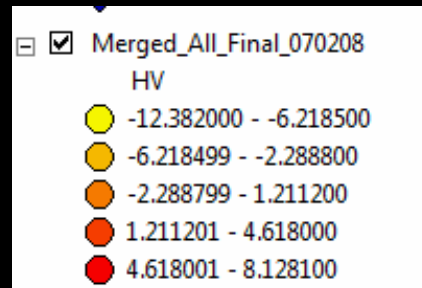


Canopy height deviation



Study site selection

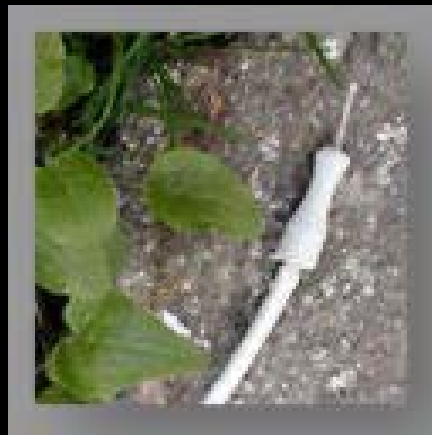
- Based on results only elevation and canopy height deviation are necessary gradients to sample for my study sites. I used a stratified random sampling method to identify low, mean and high deviation sites (10 m spatial resolution) within 3 elevation study zones.



Micro-climate measurements

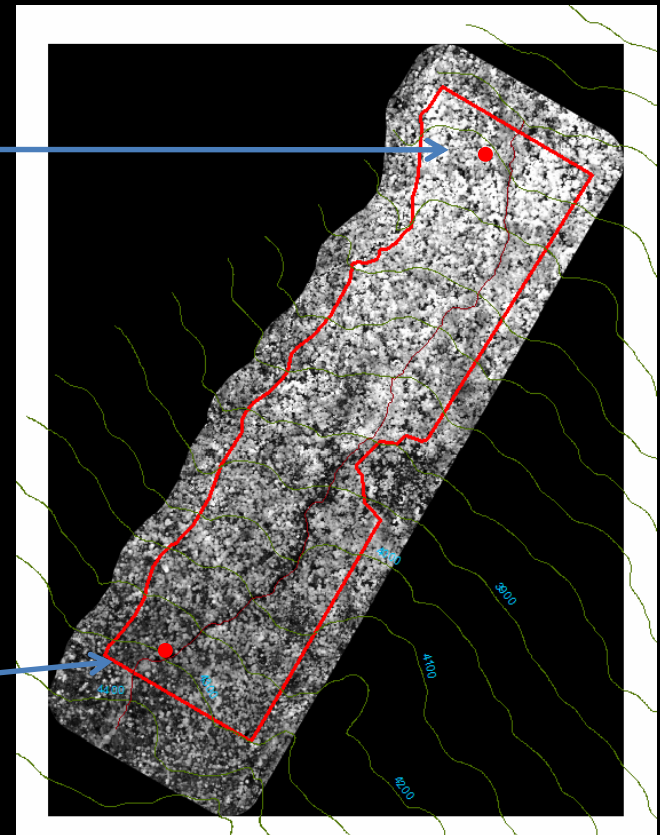
- Direct and Diffuse PAR (400 -700 nm) – directly limits photosynthesis
- Wind speed – controls leaf transpiration rates
- Humidity – controls leaf transpiration rates
- Temperature – controls rates of enzyme catalysis
- Leaf water balance not measured as all rainfall is > 3000 mm yr-1 (not limiting)

PAR + CO₂ + H₂O => CH₂O (e.g., sucrose) + O₂

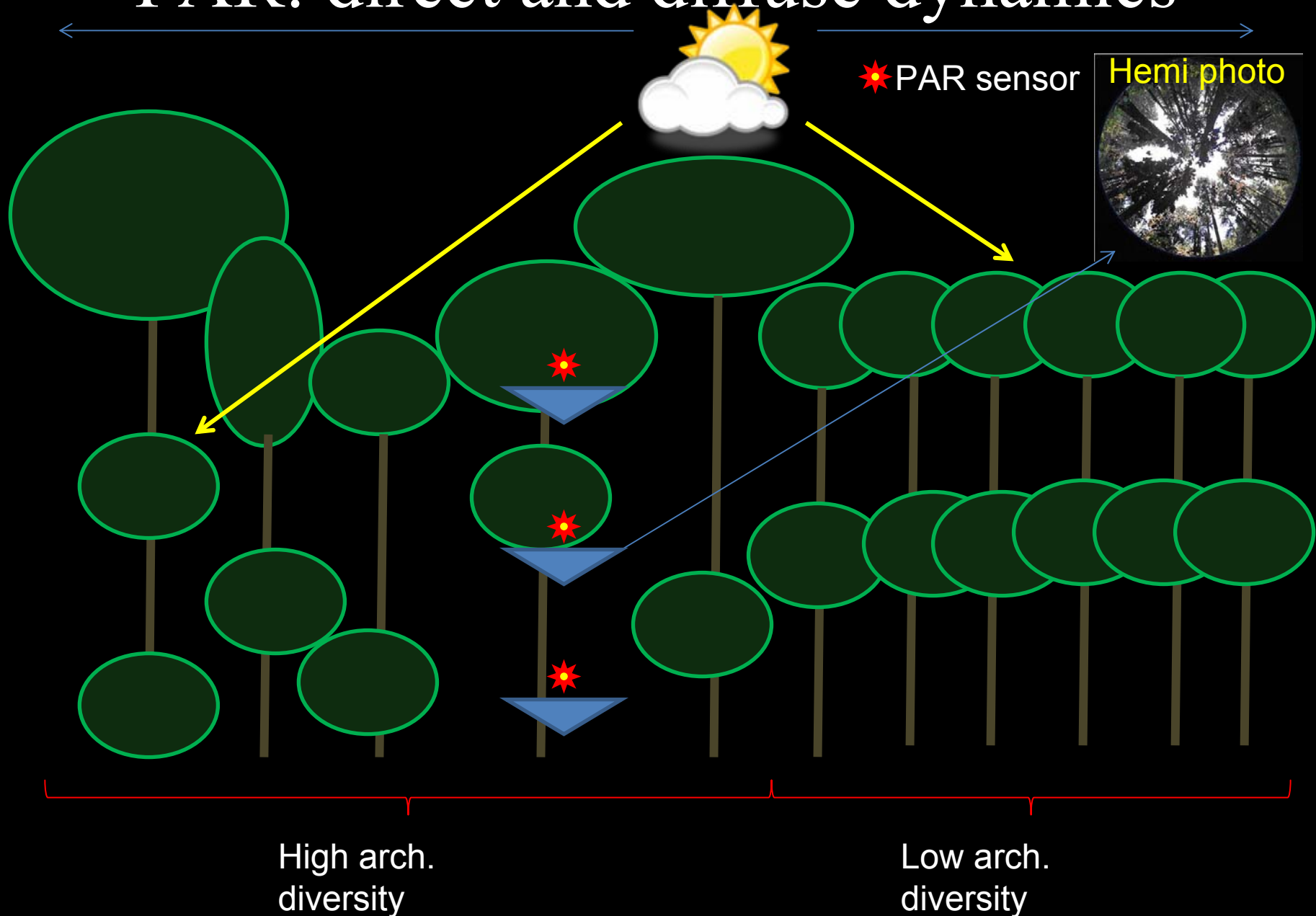


Top of canopy micro-climate

- Top of canopy weather stations are running simultaneously at low and high elevations of the transect. Data is collected every 30 seconds. Direct and diffuse PAR measurements will be collected at each location.



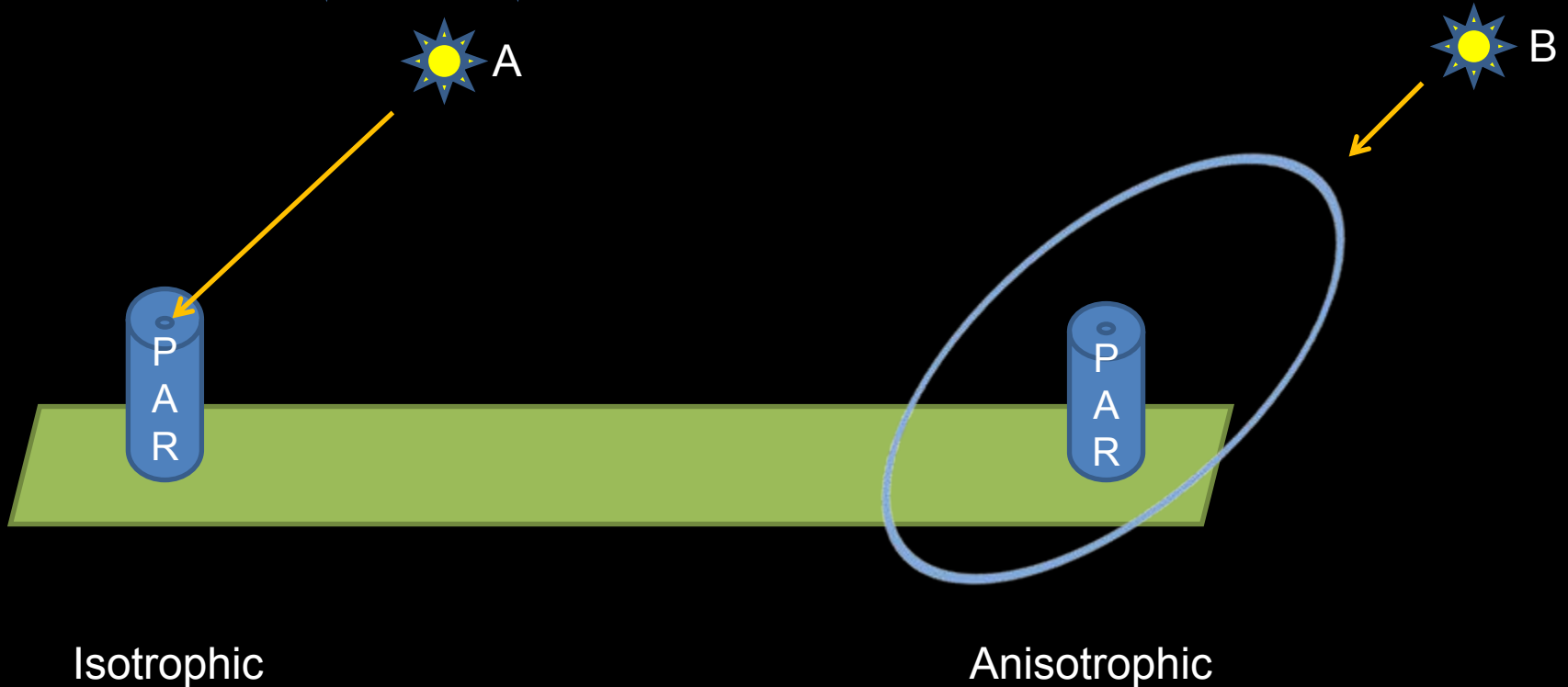
PAR: direct and diffuse dynamics



Diffuse / Direct PAR

Important component of forest structure PAR interactions
Direct and diffuse PAR penetrate forest interiors differently

$$\text{☀ B} / \text{☀ A} = \text{☁} \text{ clearness index}$$



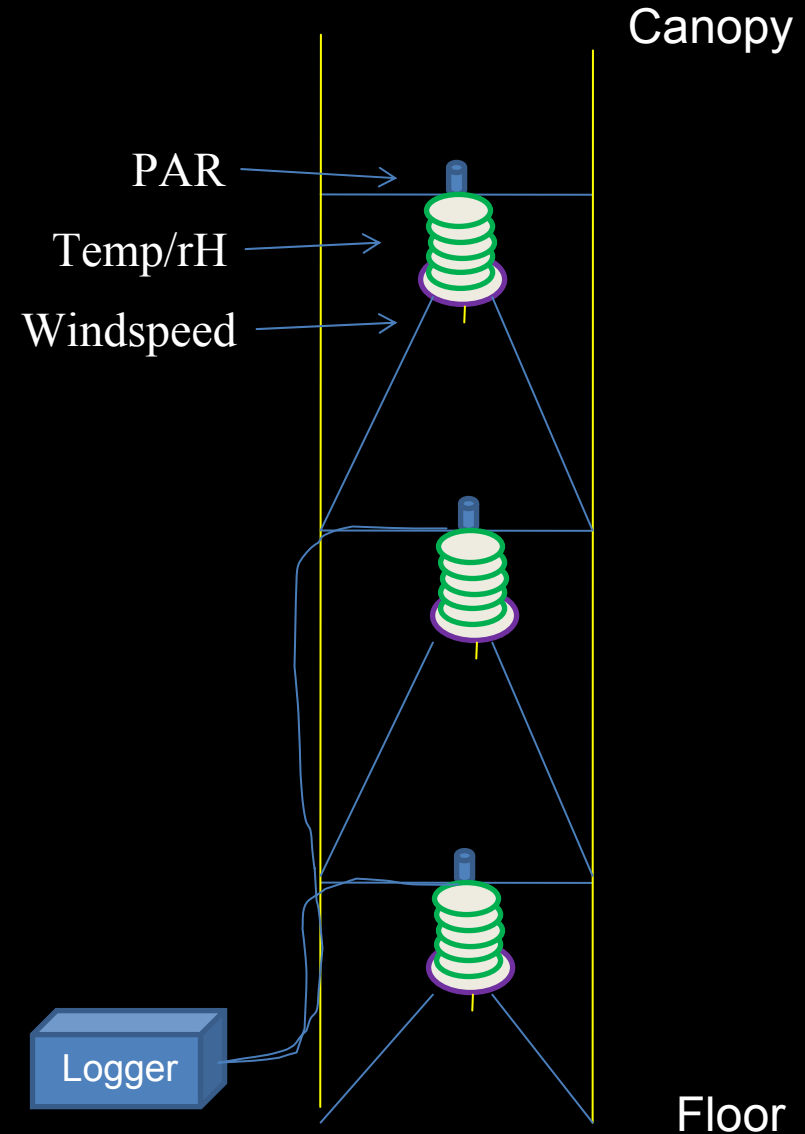
How to make a shade ring - not as simple as it looks.

- Ring angle = latitude,
- PAR sensor position follows Earth polar axis,
- Offset varies with solar track; solstice = most severe offset,
- Sensor track positioned true North (solar noon – highest sun elevation),
- Post processing models used to remove isotropic (sunny) and anisotropic (cloudy) errors resulting from the shade ring obscuring the sky.



Interior forest micro-climate

- Movable array (4 units) located randomly within study sites and location shifted weekly.
- Data collected same time scale as climate stations.
- Sensors calibrated with climate stations



● Micro-climate and photosynthesis measurements

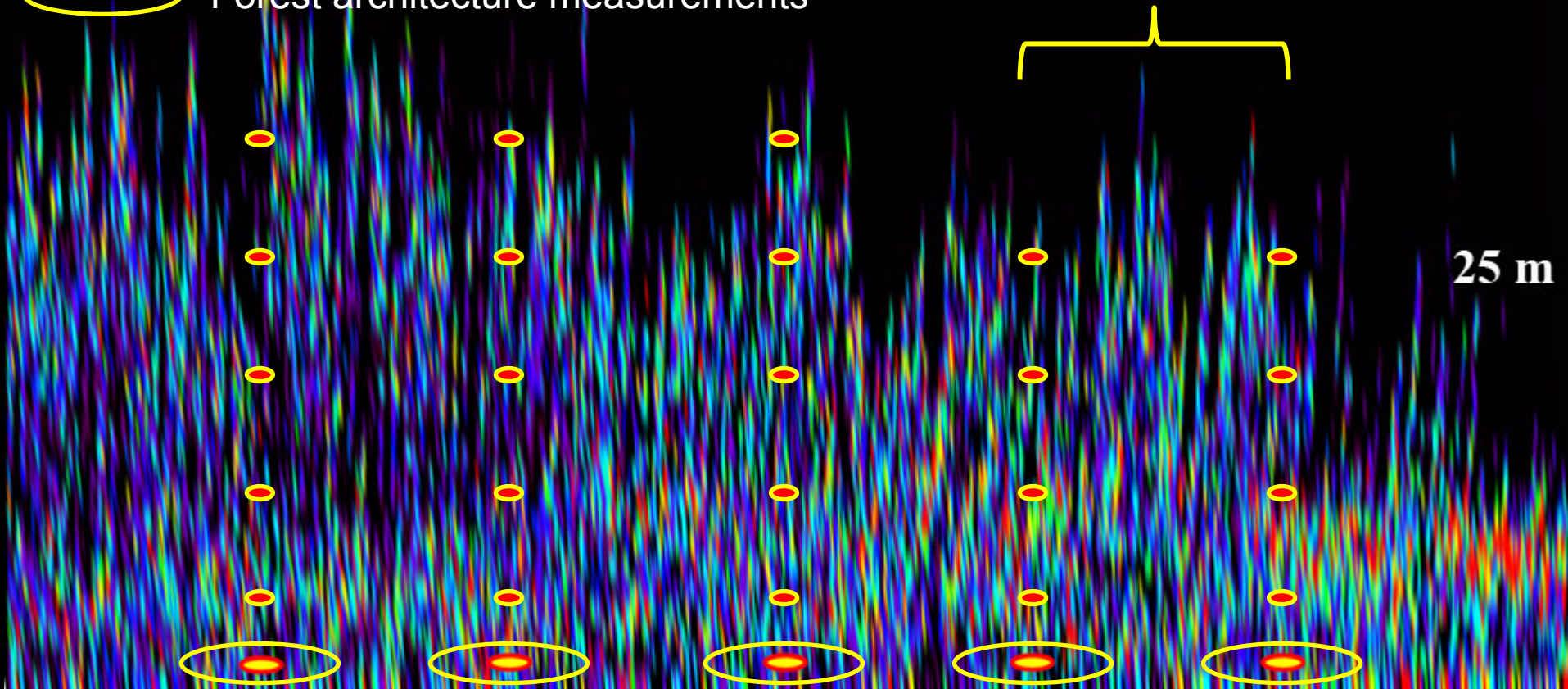
● Litterfall measurements

○ Forest architecture measurements

50 m

20 m

25 m

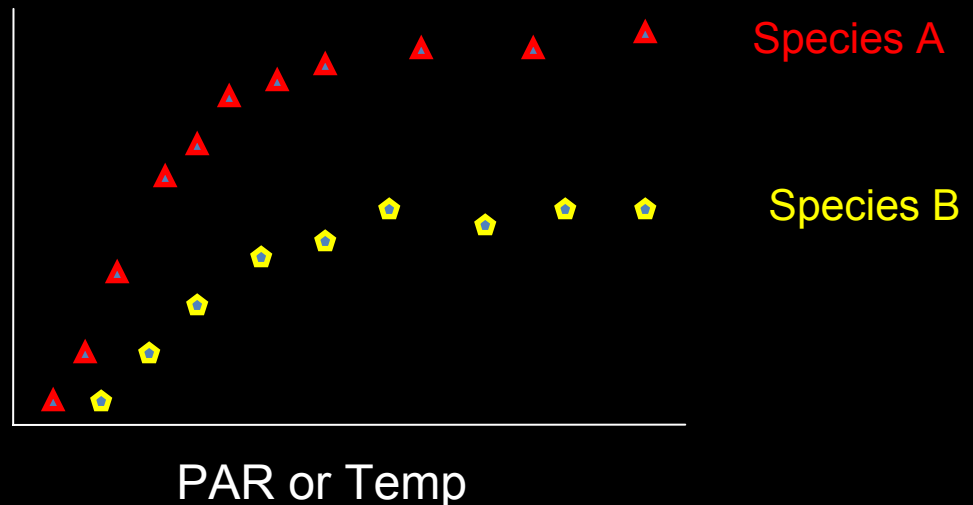


Photosynthesis measurements

- 4-6 study sites per elevation zone will be selected based on canopy access. These will be used to set up traverses for in situ photosynthesis measurements throughout the upcoming year.
- Measurements will be made on the 5-8 dominant LAI species per site.
- Primary measurements will be photosynthesis under ambient conditions of PAR, temp and rH. A smaller number of PAR and temp response curves will be made for each species.

- For each photosynthesis measurement the following data will be recorded.
 - Day
 - Time of day
 - Precise spatial location
 - Species
 - Individual max height
 - Estimated leaf age (young, mid or old)
 - All standard LiCOR 6400 output information

A

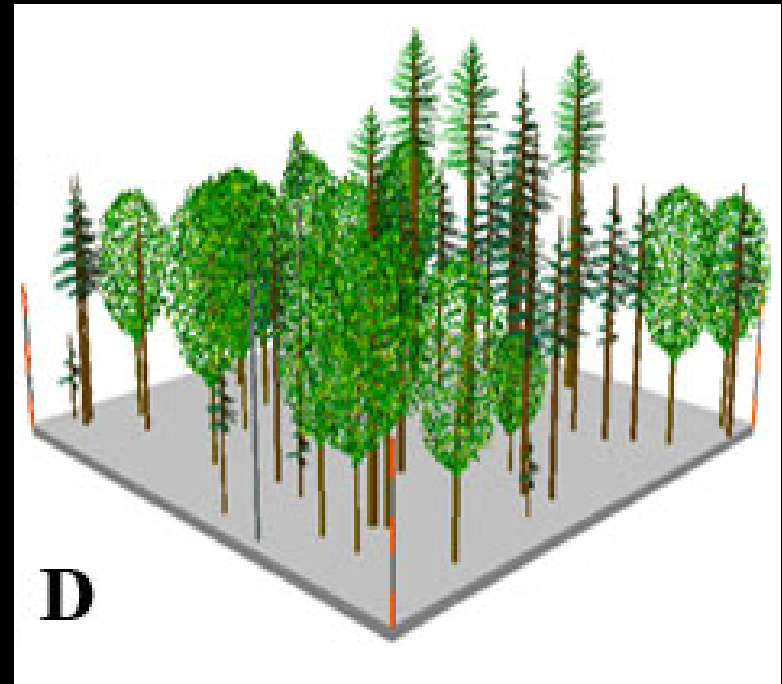


Canopy access



Modeling approach

- Structural model dealing with 201,600,000 LAD “basketballs”.
- Interior forest micro-climate will be modeled at a time scale of 1 minute throughout the study transect normalized to the top of canopy weather stations.
- Half of the interior forest micro-climate measurements will be used to parameterize the model and the other half to validate.
- Photosynthesis will be modeled using microclimate, structural location and climate station measurements as input data. The influence of species differences vs. forest architecture on total C assimilation will be quantified and compared.



Present status

- Fabricating and calibrating interior forest microclimate array,
- Fabricating and calibrating direct/diffuse PAR sensor system,
- Collecting vertical leaf profile data for LiDAR calibration,
- Rigging traverse locations,
- Calibrating and installing top of canopy climate stations.
- Prepping for a seasonal cycle (aka., year) of measurements starting ~
~January 2009.

Some acknowledgements

- Project in collaboration with: Greg Asner, Angelica Almeyda, Dave Burke, Chris Field, Eric Davidson, Peter Vitousek, Susan Cordell, and Christian Giardina
- Assisted by: Flint Hughes, Joe Berry, Jen Funk, Robin Martin, Claire Lunch, Cameron Williams, Heraldo Farrington, Rodolfo Dirzo, Kate Brauman, David Freyberg, Ty Kennedy-Bowdoin, Dave Knapp, Jeff Broadbent, Taihaku Priest and many others.
- I thank the Stanford Department of Biology and Department of Anthropology, the Carnegie Institution Department of Global Ecology and DOE GCEP Fellowship for financial support.
- Thank you!

